

## **Development of Improved Satellite-Linked Transmitters, Physiological Recorders and Attachment Techniques for Monitoring Beaked Whales**

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### **LONG-TERM GOALS**

We aim to improve upon our existing tagging and tracking methods for odontocetes and to develop new telemetry technology and attachment techniques that will advance researchers' abilities to understand the impacts of anthropogenic sound on odontocetes, especially beaked whales. The goal of Task 1 is to improve upon our existing remotely-deployed satellite tag attachment technique to achieve longer monitoring periods. The design concept will follow our current design of a miniature electronics package held outside the dorsal fin by small attachment darts that penetrate the fin but do not result in a significant adverse effect on the whale. Task 2 is the development of a new satellite transmitter in a similarly small package capable of dorsal fin attachment but with enhanced capabilities to measure and transmit behavioral information such as dive depth. For task 3 we will modify our existing technology for making physiological recordings and demonstrate its utility on beaked and pilot whales so that in the future diving physiology studies could be conducted to further our understanding of the susceptibility of these whales to adverse physiological effects of exposure to anthropogenic sounds.

### **OBJECTIVES**

This project has 3 major technological objectives:

1. Improve upon our existing remotely-deployed satellite tag attachment technique to achieve longer duration monitoring periods – aiming for up to 6 months.
2. Develop a new satellite transmitter with enhanced capabilities to measure and transmit behavioral information
3. Improve on our existing technology for making physiological recordings and test it on beaked whales or other deep divers such as pilot whales

### **APPROACH**

This project relies on a team approach that in addition to the PI includes Dr. Robin Baird and Greg Schorr of Cascadia Research Collective, and Dr. Brad Hanson of the Northwest Fisheries Science

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Center, NMFS. Additionally, the engineering and other staff at Wildlife Computers are critical to the ability of this project to produce methods and tools that can be made widely available to other biologists wishing to study the movements and behavior of beaked and other whales.

Short-term (hours to days) recordings from telemetry tags attached with suction-cups can provide tremendous insights (e.g., Baird et al. 2008), but medium- (weeks to months) to long-term (6 months to > 1 yr) observations will be needed to adequately describe the behaviors of interesting but cryptic species such as beaked whales. Telemetry can also be an extremely useful aid in designing and interpreting studies on the distribution, abundance, and habitat of beaked whales (Cox et al. 2006). Tagging of beaked whales with satellite and/or short-range VHF transmitters can also permit individuals to be located easily and will greatly facilitate focal observations of individuals during controlled playback experiments.

Our current remotely-deployed satellite tag and attachment techniques (Andrews et al. 2008) average attachment durations of approximately one month for most species, so our first objective is to improve upon this to achieve longer monitoring periods. Our current design incorporates darts and barbs made of Grade 5 titanium. We will experiment with variations in thickness, springiness, and shape of the barbs to find a design that is likely to provide extended attachment periods. We will empirically test barbed dart designs on dorsal fin tissue that we recently obtained from freshly dead stranded beaked and pilot whales. We will also work to develop a new attachment design that involves piercing the dorsal fin with a toggling harpoon, which will also be tested on dorsal fin tissue. A new tag deployment device capable of higher power will be developed along with improved arrow designs with better balance and flight trajectory. This will allow delivery of the tags at higher velocities and greater accuracy, assisting in complete dart penetration and therefore better attachments and attachment duration, as well as allowing for deployments of tags from a greater distance. The final stage will be to deploy the best designs and observe their performance on beaked whales and other deep diving odontocetes in the field.

Our second major objective is to develop a new satellite transmitter with enhanced capabilities to measure and transmit behavioral information. The satellite transmitter that we have recently deployed on beaked whales is a location-only transmitter. In order to gather longer-term data on foraging behavior and time spent at depth we will work with a commercial telemetry manufacturer (Wildlife Computers) to develop a new tag that incorporates a depth sensor and new compression software in the same small form factor that we've been using successfully on beaked whales.

Our third objective is to improve on our existing technology for making physiological recordings and apply it to beaked whales in order to understand their susceptibility to adverse effects of exposure to anthropogenic sounds. We have an 8 channel archival datalogging device that we have used to measure the electrocardiogram (ECG), breathing frequency, body temperature, 3-axes of acceleration, flipper stroking frequency, dive depth and water temperature in pinnipeds. We propose to modify this device for use on beaked whales and other deep diving cetaceans.

## **WORK COMPLETED**

Our current tag attachment design consists of titanium darts with backwards facing barbs in a petal shape bent in an arc away from the shaft of the dart. To determine the efficacy of the petal barbs and their holding power, we conducted several tests with different petal materials. Stainless darts and barbs were assessed because stainless has better shape memory and barbs made of stainless might provide

greater hold in the tissue. However, the density of stainless steel resulted in a mass that was too heavy for good ballistics. Therefore we decided to retain medical-grade (Gr. 5) titanium and focused on testing the effect of varying the petal material thickness. Darts were made up with the 0.016" thick petals that we have used on most deployments through 2008, and with new 0.020" thick petals. These darts were then fired into a layer of rubber which simulated passing thru dorsal fin material. The change in shape of the petal and the degree of outward bend was then measured to determine which petal thickness retained the most 'springy' characteristics after penetration. Tests of dummy satellite tags with various titanium dart and barb setups were conducted using dorsal fins collected from stranded animals to assess the process of dart penetration into the fin. We attempted to use ultrasound on the fin to look at real-time interaction of the dart and tissue, but because of the low hydration state of the carcass dorsal fin material, ultra-sound conduction was limited and imaging was not possible. We then switched to digital X-rays to attempt to assess the same questions. Darts were fired into the dorsal fin, then X-rayed in-situ. The tag body and dart was then pulled backwards in line with the entry penetration, first applying 11.4 kg of external force, and another series of X-rays were taken. A slight outward movement of the dart was noted upon the first 11.4 kg of pull. A second reverse pull of 22.7 kg was then exerted on the dart and further X-rays were taken. The amount of force exerted on the darts during these tests was not based on forces that we estimate will occur with tagged whales due to hydrodynamic drag exerted on the tag, but were chosen to try to simulate what was happening to the petals over longer periods of time with consistent drag.

We also worked to improve the performance of the location-only satellite tag that we have been using. In 4 cases out of 68 deployments, our previous version of the satellite tag cracked upon impact as verified in photographs. The cracks occurred around the distal ends of the tag, where the darts attached. While some of these tags continued to transmit for some time after cracking, it is likely that transmission durations were shortened due either to the integrity of the attachment, or water intrusion into the electronics along the cracks. These smaller cracks may have occurred on other deployments, but because of the difficulty in spotting them they may not have been documented. To minimize the potential for cracking, we sought to strengthen the tag. Cut glass fibers were added to the epoxy resin during the casting process to add strength around the dart attachment points, and the manufacturing process was changed to ensure better consistency of epoxy coverage around the batteries and electronic components. Six tags of the new design were tested for robustness in impact and pressure testing. Impact testing consisted of firing the tags into a hard rubber target backed by a large boulder weighing over 1000 lbs to best simulate the most extreme impacts the tag might encounter. All 6 tags were fired into the target between 1 and 11 times at a range of 3.5 - 5 meters. Shots were taken both in normal orientation to the target (90 degrees) and at the extreme angle of 45 degrees to target, which will put much greater forces on the individual darts (and increase the likelihood of cracking on impact). No visible cracks which would lead to integrity issues were observed. To investigate possible micro cracks, the tags were placed in a Ziploc bag filled with red-fluorescing dye, and placed in a pressure chamber. Tags were cycled 8 times to a depth of 800 -1000+ meters, then dropped to 1000 meters and left at depth for 15 minutes. A visual inspection of the tags using both a microscope and an infrared light (to fluoresce any dye intrusion) was made. Slight delamination of fiberglass washers around the helicoils was seen in two tags, but no dye intrusion was noted suggesting no cracking during the impact testing. A change in the construction process was made to eliminate the delamination of washers.

The new location-only satellite tags with the new dart/petal barb configuration were deployed on 4 pilot whales and 1 Blainville's beaked whale on the leeward side of the Big Island of Hawaii in April and May of 2009 to compare with attachment durations of the previous tag and dart petal configuration.

An additional goal was to develop and test a new tag deployment device for more accurate tag delivery and attachment. Several different tag projectors were considered. We assessed the Air Rocket Transmitter System (ARTS; Heide-Jorgensen et al. 2001) and a modified ARTS, both currently in use by other researchers for remotely-applying satellite tags to larger whales. We also investigated what types of design changes would improve the performance of the projector that we currently use, a modified Dan-Inject remote tranquilization rifle. Calculations suggested that enlarging the barrel diameter from 13mm to 20mm would result in an increase in velocity of approximately 35%, while also allowing for modification to the arrow for better ballistics. Therefore, we designed and machined a new barrel and receiver for empirical testing.

We worked with engineers at Wildlife Computers to develop a new satellite tag capable of measuring and transmitting behavioral information such as dive depth. Prototypes of the new tag are expected by the beginning of October 2009. We have also modified our solid-state ECG and dive behavior monitor for use on beaked whales and other deep diving odontocetes. The tag requires two ECG electrodes to be placed on the flank of the whale with a separation of at least 20 cm, making it nearly impossible to attach using remote projection with our pneumatic rifle. Therefore, we are currently working on a pole-mounted device to hold and attach this tag.

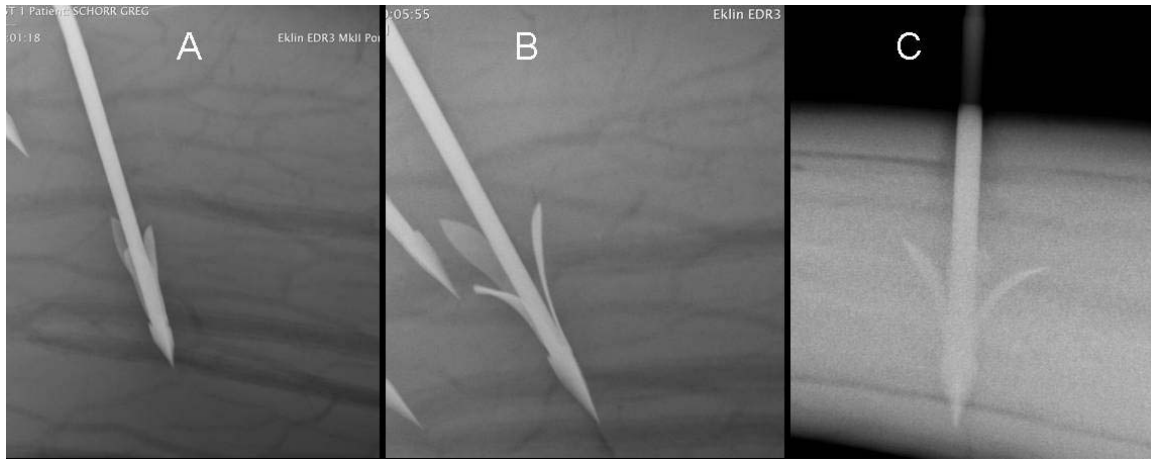
## RESULTS

After test firing darts with various barb designs, we found that the 0.020" petals compressed ~4 % less than the 0.016" petals, meaning they retained their 'springiness' better than the original 0.016" petals. In the test shots into real dorsal fin material, we found that a slight outward movement of the dart was noted upon the first 11.4 kg of pull (Figure 1a, b). Analysis of the X-rays showed the petals had begun to splay outward from the dart shaft, grabbing onto the dorsal tissue as designed (Figure 1c). After 22.7 kg of pull, the petals were most often splayed out even further. We had been concerned that the petal barbs made with thicker and therefore stronger material may have caused the barbs to easily cut the tissue during the pull back and just cut their way out instead of getting caught in the tissue, but in fact these barbs splayed out inside the tissue and resisted further outward migration. The combination of the 'springiness' tests and the digital x-ray work led us to reduce the width of our previous petals by 20% in order to minimize tissue damage upon entry while still maintaining enough retention power. We switched to using 0.020" thick material for the primary (longer) row of petals, and 0.016" material for the secondary (shorter) row of petals.

In order to assess the performance of our newly modified location-only satellite tag and dart/petal barb design, the new setup was deployed on 4 pilot whales and 1 Blainville's beaked whale in 2009. The tag attached to the Blainville's beaked whale never transmitted. A few other tags have failed upon attachment with no visible sign of cracking or other malfunction and we are currently investigating potential causes of these failures. Median attachment duration of the 4 pilot whales tagged in 2009 was 62.4 days (range = 25 – 110) compared to 34.9 days (range = 11 – 72, n = 18) for tags of the previous construction and dart type, representing a 77% increase in duration of signal transmission, and likely tag attachment.

In order to develop a better tag delivery system we tested the ARTS and determined that the accuracy and usability was not adequate when attempting to tag fast moving, small odontocetes. The major flaw is an imprecise trigger mechanism. Testing of our modified Dan-Inject projector is still underway, but initial results suggest an at-target increase of approximately 32% (relative to the theoretical 35%). These changes should allow for longer shots to be taken with a straighter tag trajectory, and also allow

for the deployment of heavier tags over the target distances we usually work at. The larger barrel will also allow room for the installation of trajectory-stabilizing fins to be added to the arrow shaft. These improvements will increase our ability to deploy satellite tags on species such as beaked whales that are difficult to approach and will also permit us to deploy heavier tags, such as the new depth-transmitting satellite tag that we are developing.



**Figure 1. A: X-ray image showing a dart in killer whale dorsal fin material after dart penetration. Note the backward facing petals are tight against the dart shaft, indicating that they were compressed upon entry into the fin which will minimize tissue damage upon entry. B: X-ray image of the same dart in A, after 11.4 kg of outward pull was exerted on the dart shaft. Note the petals have splayed outward from the dart shaft as they cut through tissue and moved into the holding position as designed. C: X-ray image of the same dart after 22.7 kg of outward pull. The petals have more fully splayed outward from the dart shaft and are now presenting a flat surface nearly perpendicular to the axis of outward force.**

## IMPACT/APPLICATIONS

Understanding the potential for impacts of naval activities on protected species of marine mammals, as well as estimating the number of individuals potentially impacted (necessary for meeting NEPA requirements), and mitigating such impacts (required for compliance with MMPA and ESA regulations), all requires information on movements and habitat use. There is considerable uncertainty in population sizes, fidelity to areas (including naval ranges), and responses to naval exercises of beaked whales and other deep divers. The development of tag technologies and deployment techniques outlined here will make a significant contribution to the ability of researchers to track movements, monitor behavior, and determine distribution of species of interest. The improvements that we have made to our location-only satellite tag and attachment system have already resulted in attachment durations well beyond our expectations and are currently being shared with other researchers so that they also can benefit from these advances.

## TRANSITIONS

The modified location-only satellite tag was developed with engineers at Wildlife Computers and this company now offers the tag as a product for general sale. Other biologists have already purchased the satellite tag and have attached it to beaked whales in projects funded by the U.S. Navy.

## RELATED PROJECTS

The National Marine Fisheries Service Southwest Fisheries Science Center is supporting research on beaked whale movements in Hawaiian waters (Baird et al. 2009). Tag and deployment developments from this work are being incorporated into these ongoing studies. See [www.cascadiaresearch.org/hawaii/beakedwhales.htm](http://www.cascadiaresearch.org/hawaii/beakedwhales.htm).

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## PUBLICATIONS

Schorr, G.S., R.W. Baird, M.B. Hanson, D.L. Webster, D.J. McSweeney, and R.D. Andrews. Movement patterns of satellite tagged Blainville's (*Mesoplodon densirostris*) beaked whales off the island of Hawai'i: implications for a greater risk of anthropogenic impacts. *Endangered Species Research* [in press, refereed].